A Multi-band High Selectivity FSS for Ka-Band Applications

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Abstract

This presentation discusses a new method to implement Frequency Selective Surfaces (FSSs) with high selectivity for satellite applications. For such applications, received signals can be separated by both the reflection and the transmission of an FSS. The FSS can be realized by combining different bandpass and bandstop structures on the same plane. Passbands and stopbands of the FSS can be tuned by choosing appropriate dimensions of the structures. By doing so, multiple passbands and stopbands of an FSS can be obtained. A prototype FSS at around 40 GHz is designed and tested in free space to verify the proposed design. The proposed method can also be used for multi-layer FSS designs.

Index Item: Bandpass, bandstop, frequency selective surface (FSS), millimeter-wave, reflection, spatial filter, transmission

Biography

Jiafeng Zhou received a B.Sc. degree in Radio Physics from Nanjing University, Nanjing, China, in 1997, and a Ph.D. degree from the University of Birmingham, Birmingham, U.K., in 2004. His doctoral research concerned high-temperature superconductor microwave filters. From July 1997, for two and a half years he was with the National Meteorological Satellite Centre of China, Beijing, China, where he was involved with the development of communication systems for Chinese geostationary meteorological satellites. From August 2004 to April 2006, he was a Research Fellow with the University of Birmingham, where his research concerned phased arrays for reflector observing systems. Then he moved to the Department of Electronic and Electrical Engineering, University of Bristol, Bristol, U.K until August 2013. His research in Bristol was on the development of highly efficient and linear amplifiers. He is now with the Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool, UK. His current research interests include microwave power amplifiers, filters, electromagnetic energy harvesting and wireless power transfer.

Outline

- Motivation
  - Satellite communications
- mmWave and THz FSS
  - Reflection and transmission
  - Selectivity
  - Multiple passbands or stopbands
- Summary

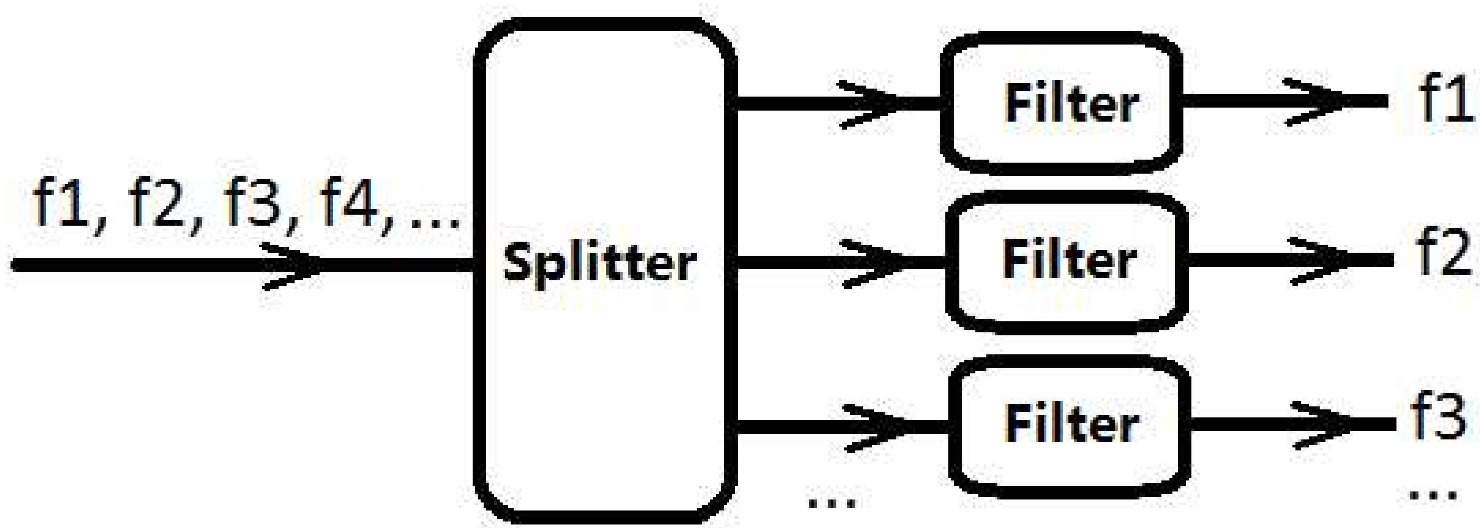
Frequency Selective Surfaces for Satellite Applications

- Satellite Applications

35 GHz
54 GHz
166 GHz
183 GHz
243 GHz
325 GHz
…

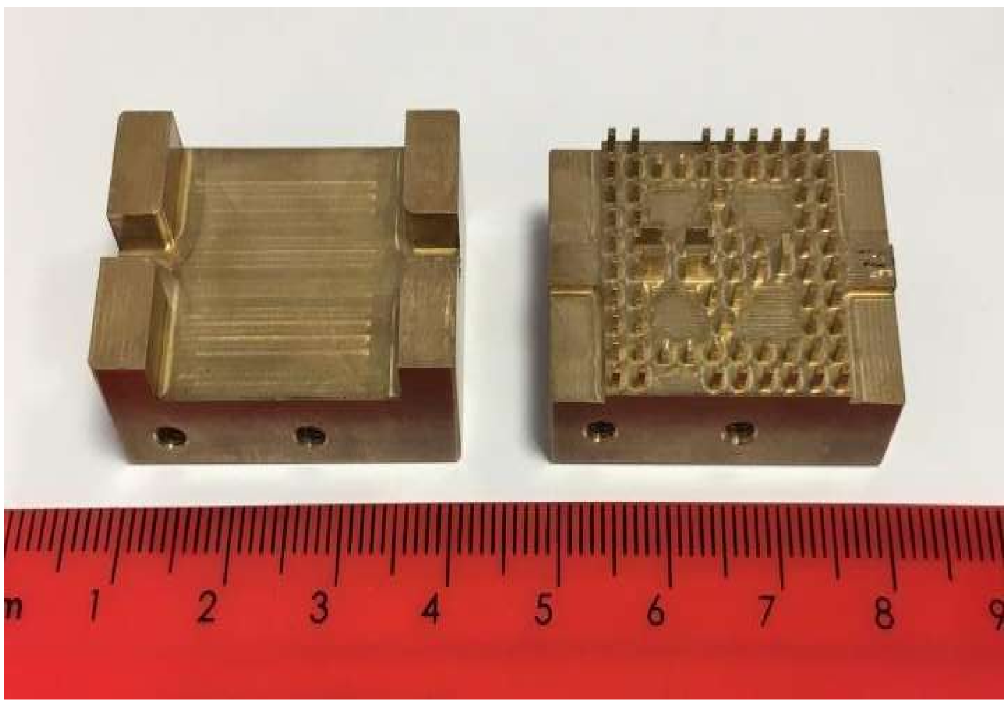
Frequency Selective Surfaces for Satellite Applications

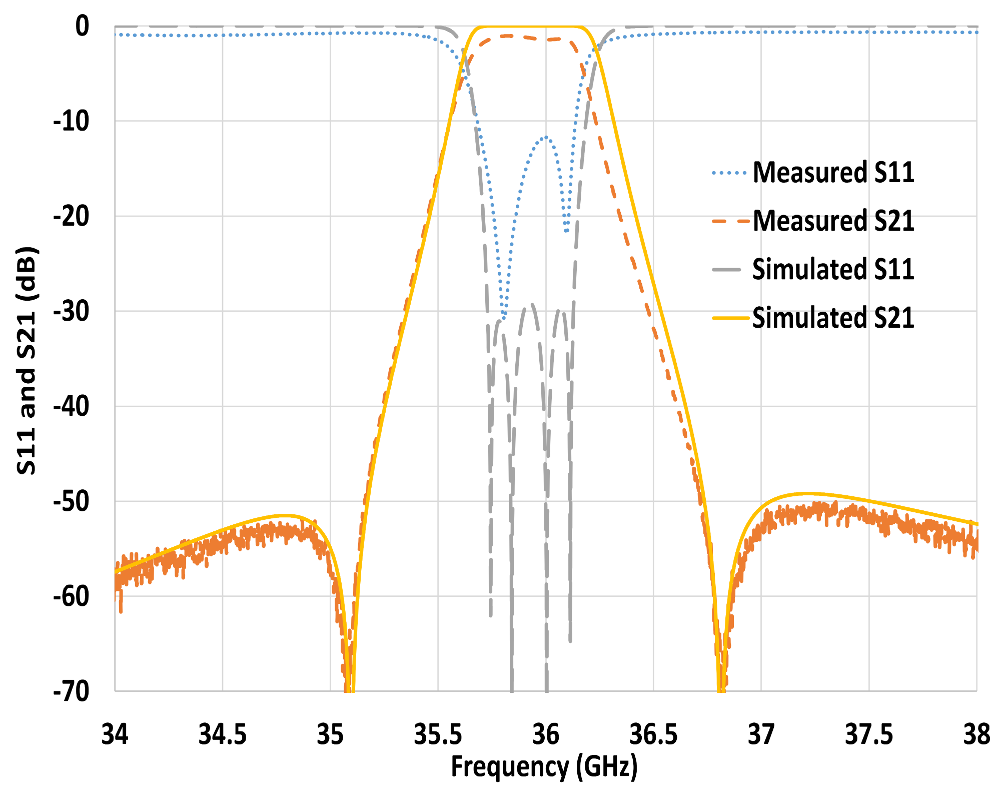
- How to split the signals: splitting and filtering?
  - Intrinsic loss of splitters
  - Wideband splitters
  - Sharp selectivity of filters
  - Difficulties in fabricating mmWave and THz devices



Differences Between an FSS and a Connectorized Filter

- Connectorized splitters and filters
  - Filters: S_{11} "wasted", sharp selectivity
  - Splitters: 3 dB loss of a two-way splitter

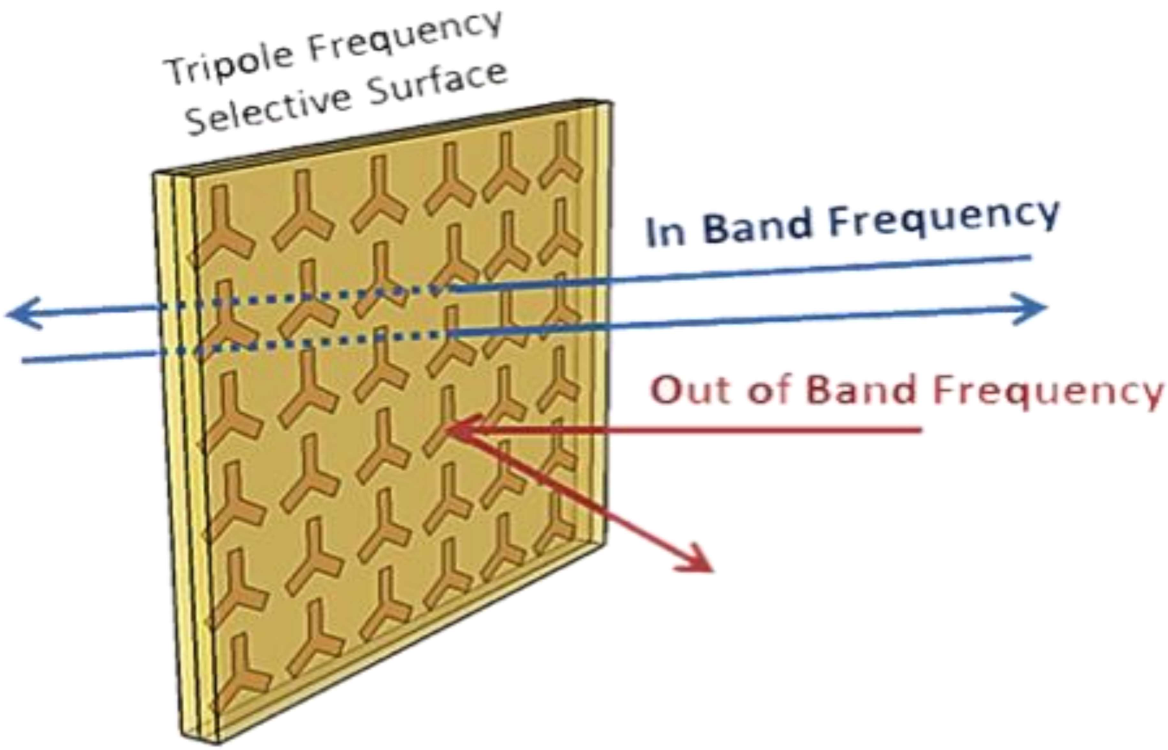




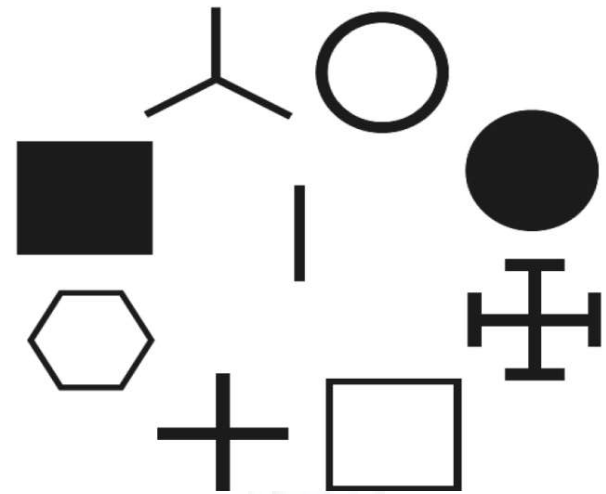
B. Al-Juboori, J Zhou et al, "Millimeter Wave Cross-Coupled Bandpass Filter Based on Groove Gap Waveguide Technology", UCMMT, 2017.

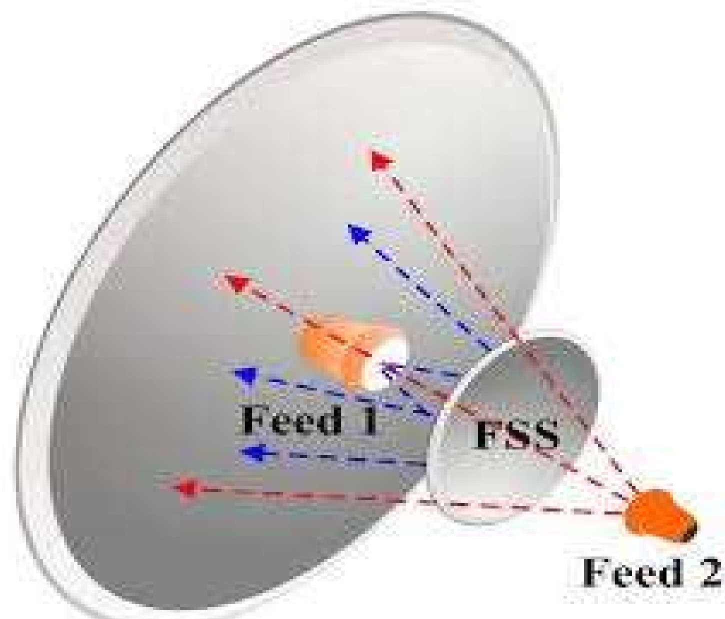
Differences Between an FSS and a Connectorized Filter

- Frequency Selective Surfaces (FSS)
  - An FSS is essentially a spatial filter
  - Element shapes



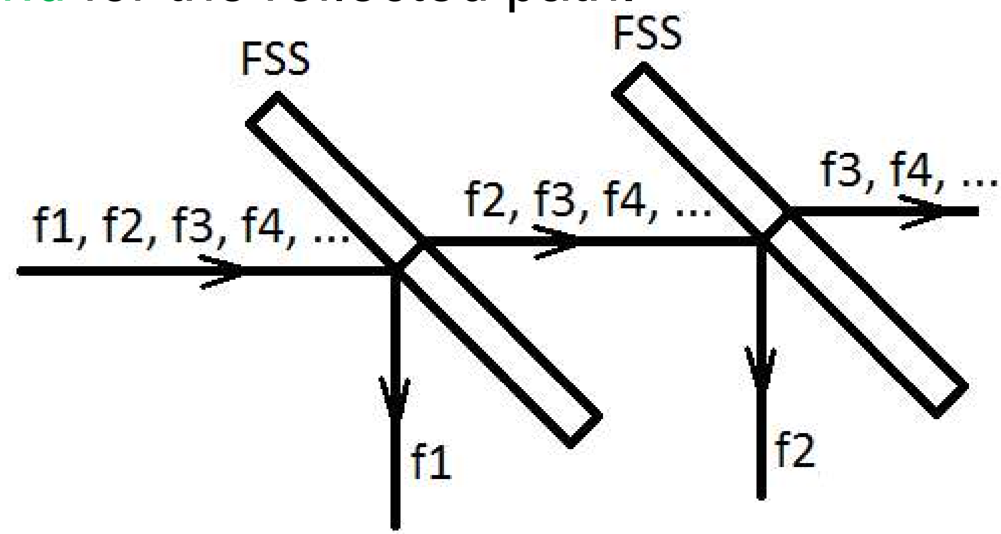
(http://www.scielo.br/)





Advantages of Using an FSS at mmWave and THz

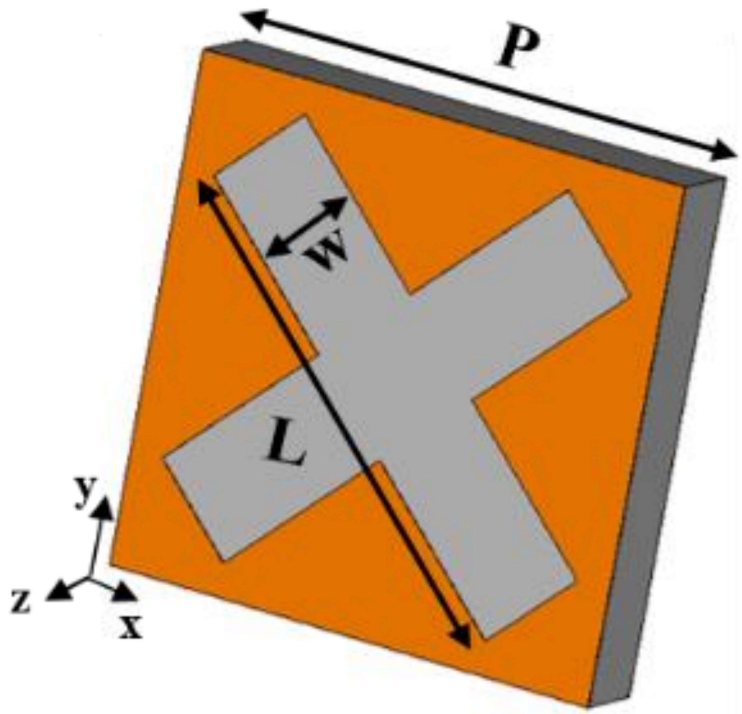
- Signals separated by both transmission and reflection
  - Realizing a transmission zero will not only improves the selectivity of the transmitted path, but also creates a passband for the reflected path.

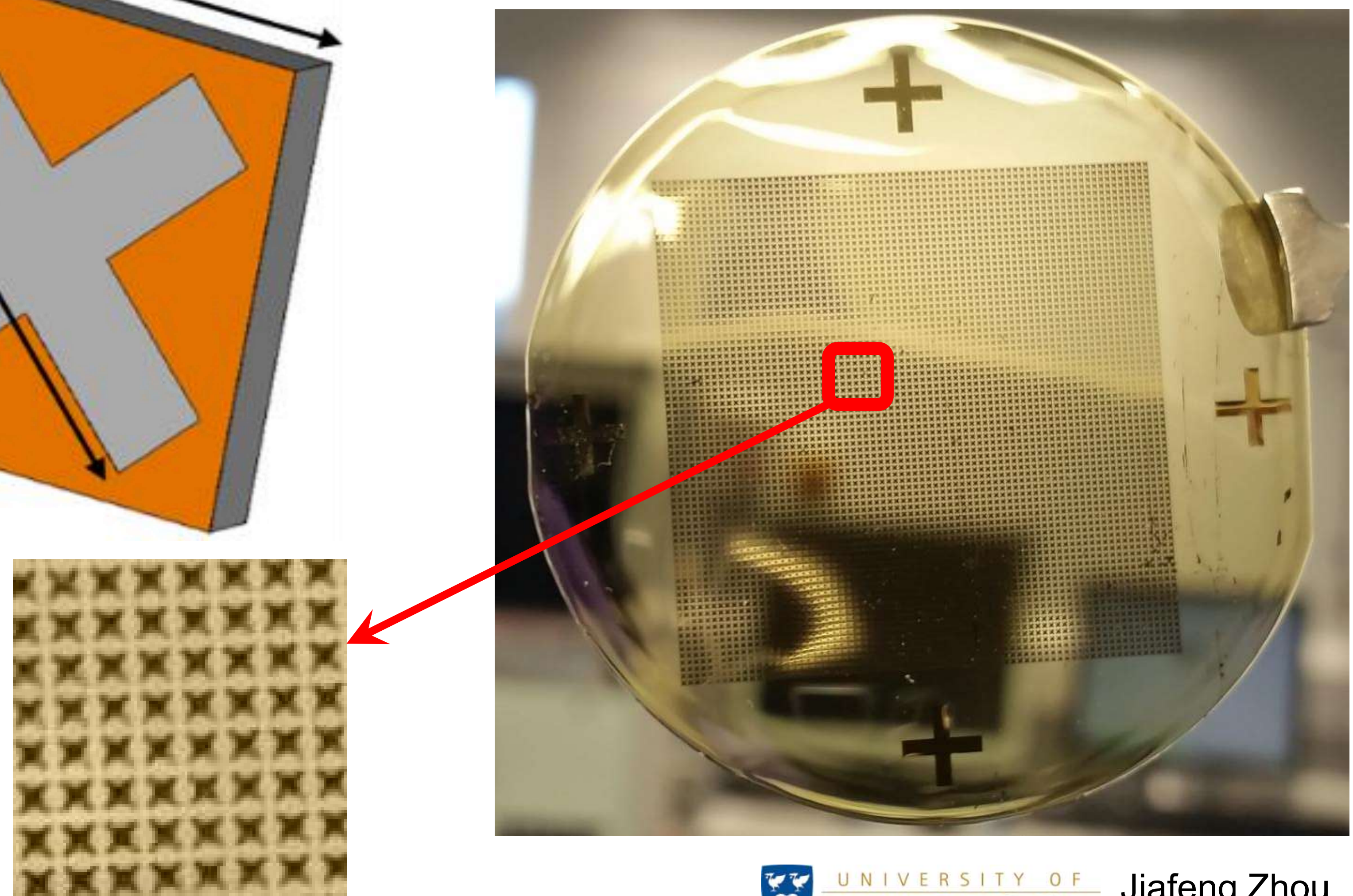


- Two FSSs can co-exist on the same layer.
  - A bandstop filter can be realized by combining two bandpass filters. A bandpass filter can be implemented by combing two bandstop filters, and so on.
  - To be discussed later….

Fabrication of an FSS at mmWave and THz

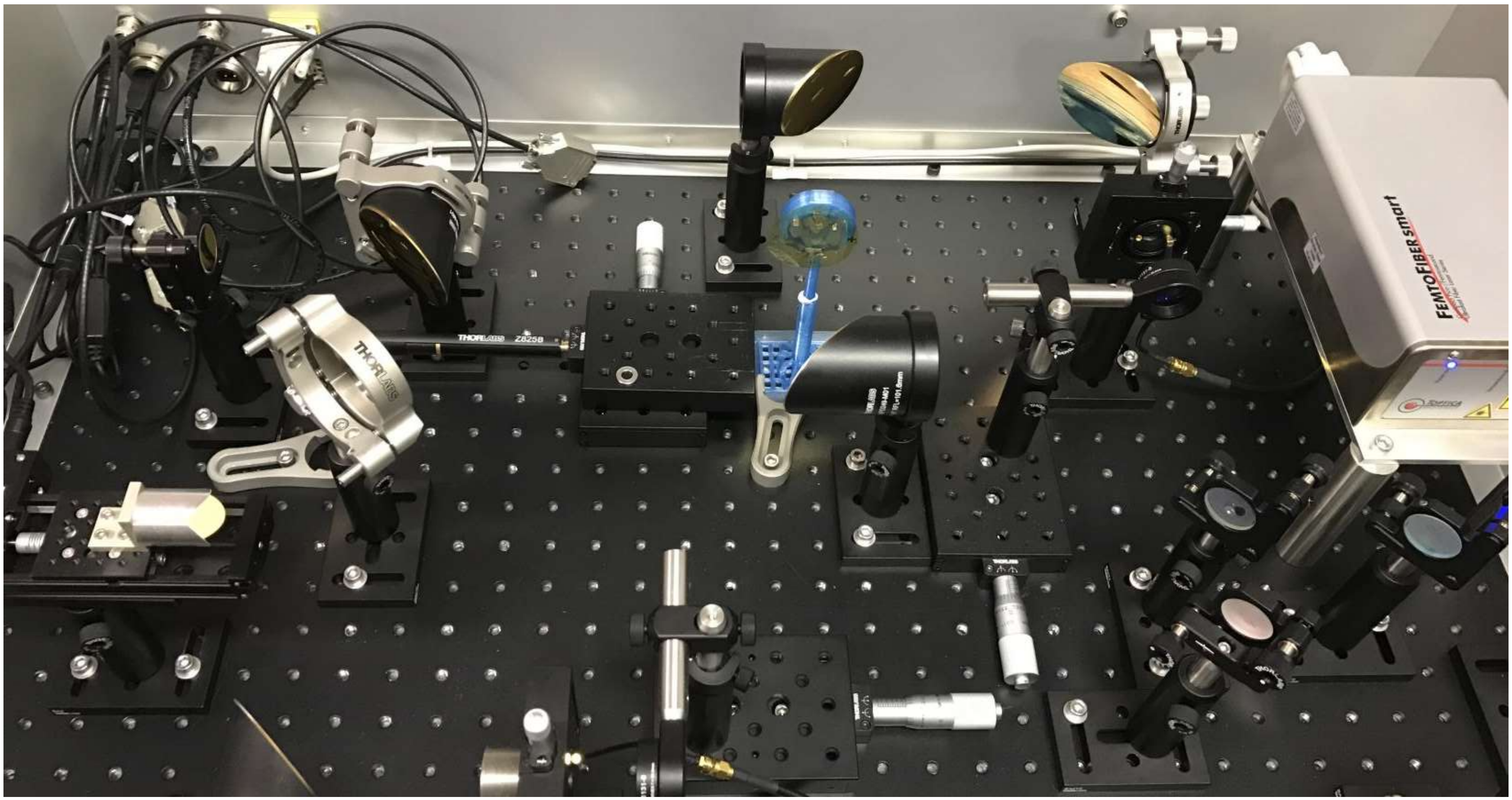
- Fabricated on a 7.5 µm thick Polyimide (PI)





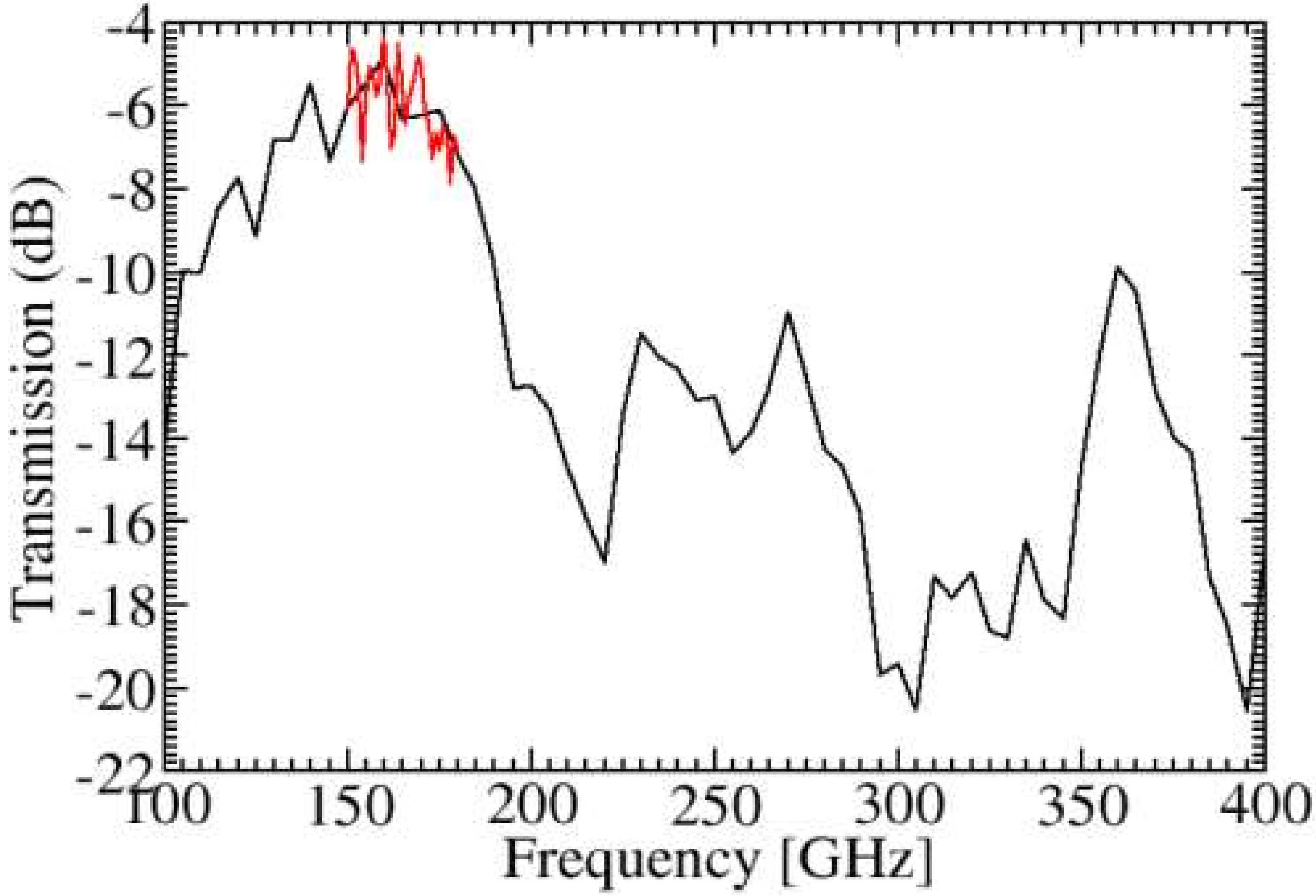
Measurement of an FSS at mmWave and THz

- Time-domain measurement



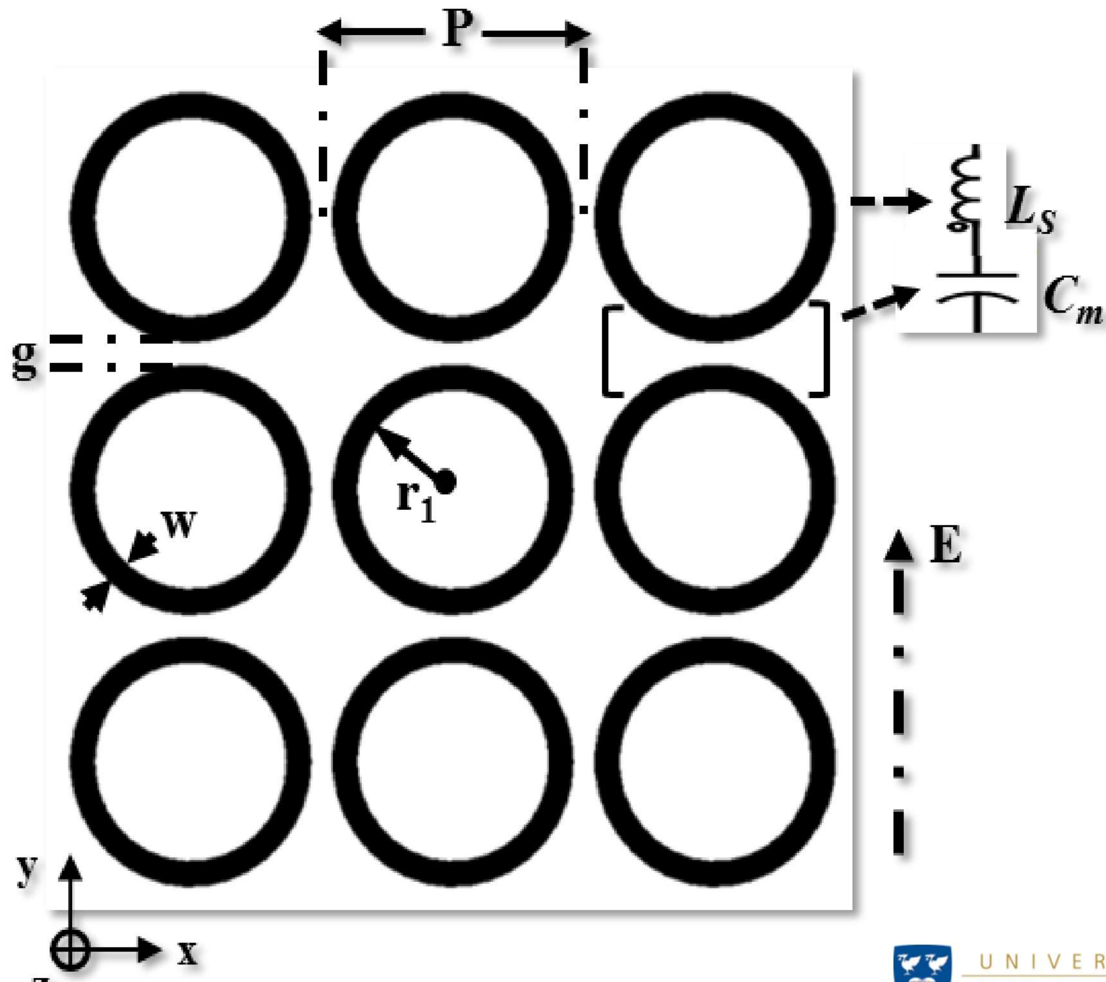
Disadvantages of Using an FSS at mmWave and THz

- Disadvantage of an FSS: poor selectivity
  - Low-resolution scan (black line) and high-resolution measurement (red line)



How to Improve the Selectivity of an FSS

- Combining Two Structures: Naturally Easy for FSSs
  - A ring array FSS has a bandstop response
  - Equivalent circuit: LC in series



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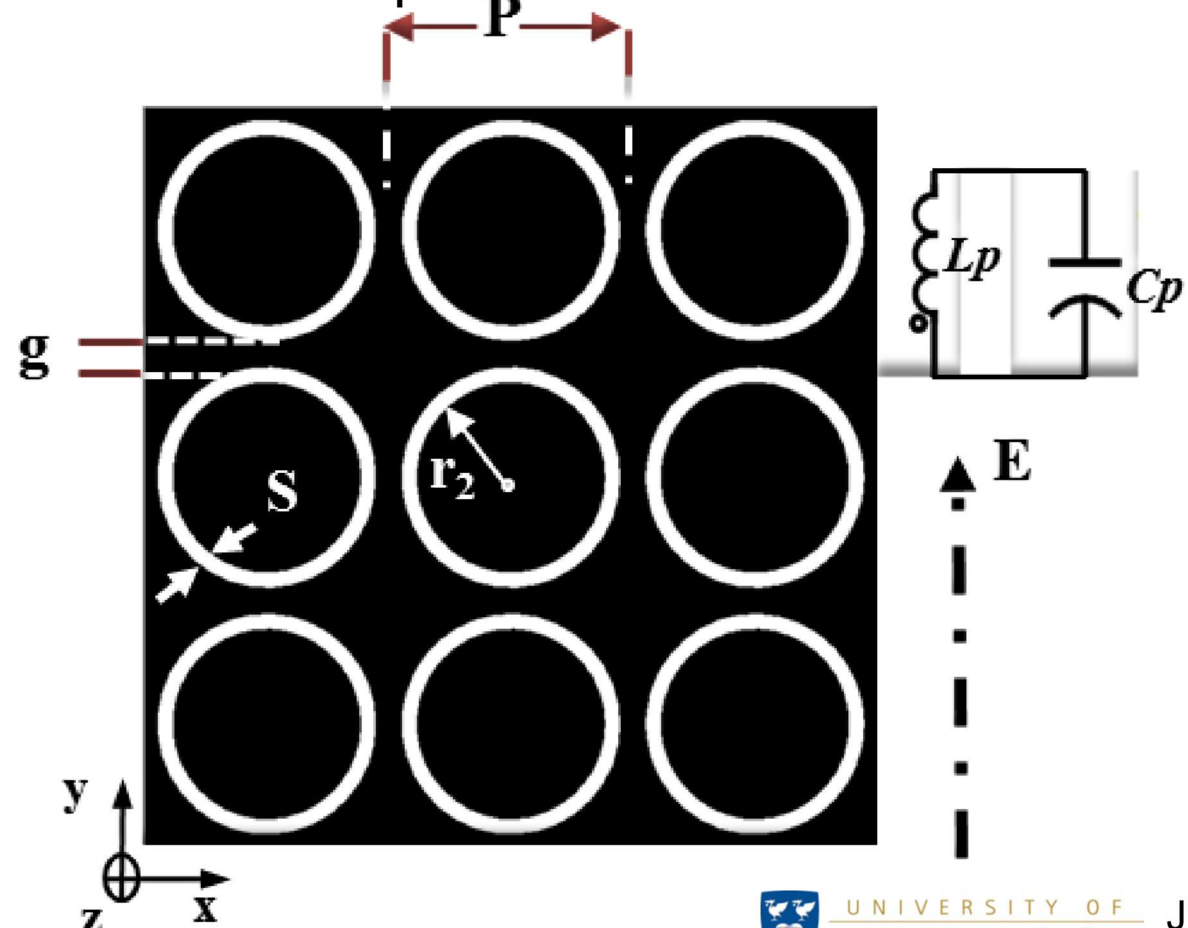
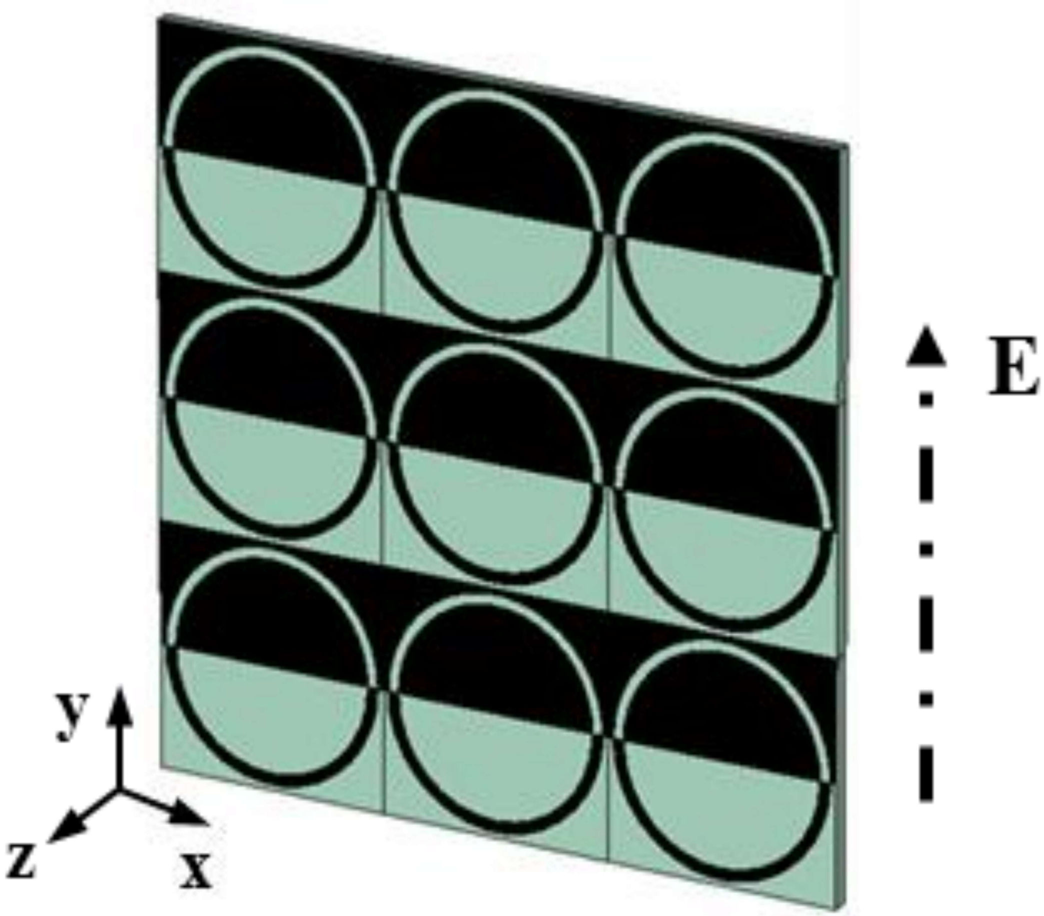
How to Improve the Selectivity of an FSS

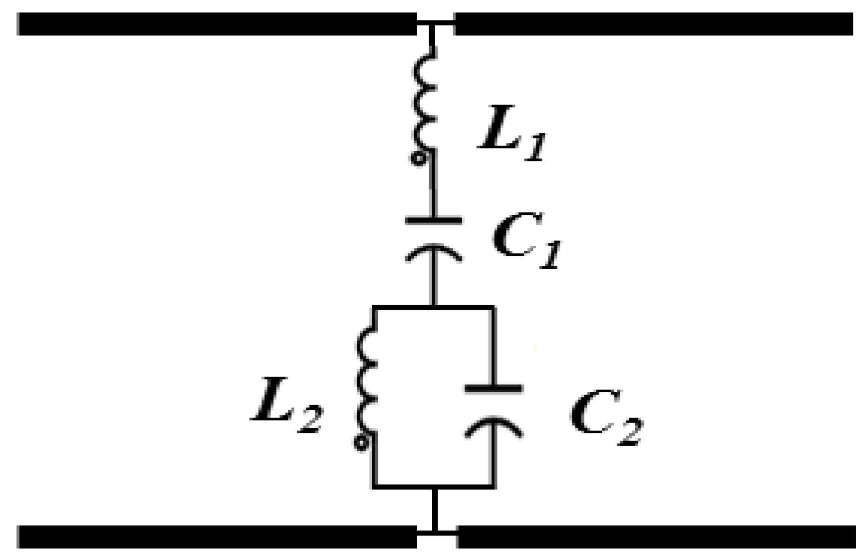
- Combining Two Structures: Naturally Easy for FSSs
  - A slot (complementary structure of a ring) array has a bandpass response.
  - Equivalent circuit: LC in parallel



How to Improve the Selectivity of an FSS

- Combining Two Structures: Naturally Easy for FSSs
  - Combining together (half-half) …
  - Equivalent circuit: LC in series + LC in parallel





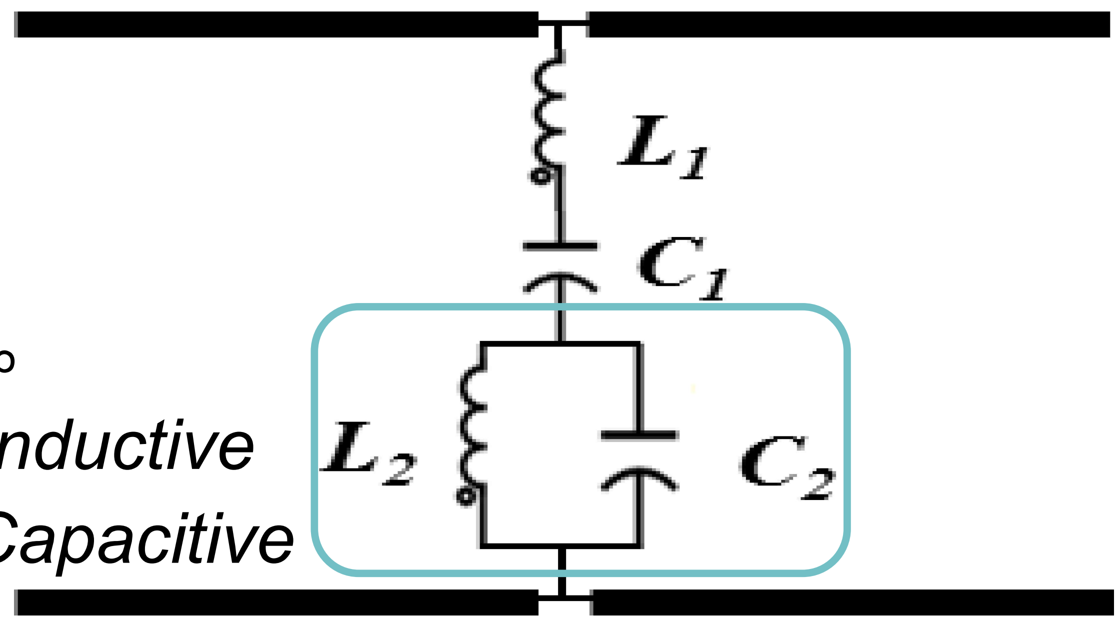
How to Improve the Selectivity of an FSS

- Combining Two Structures: Naturally Easy for FSSs
  - Combining together…
  - One passband + two stopbands!

$f = f_0 \Rightarrow \infty$

$f < f_0 \Rightarrow$ *Inductive*

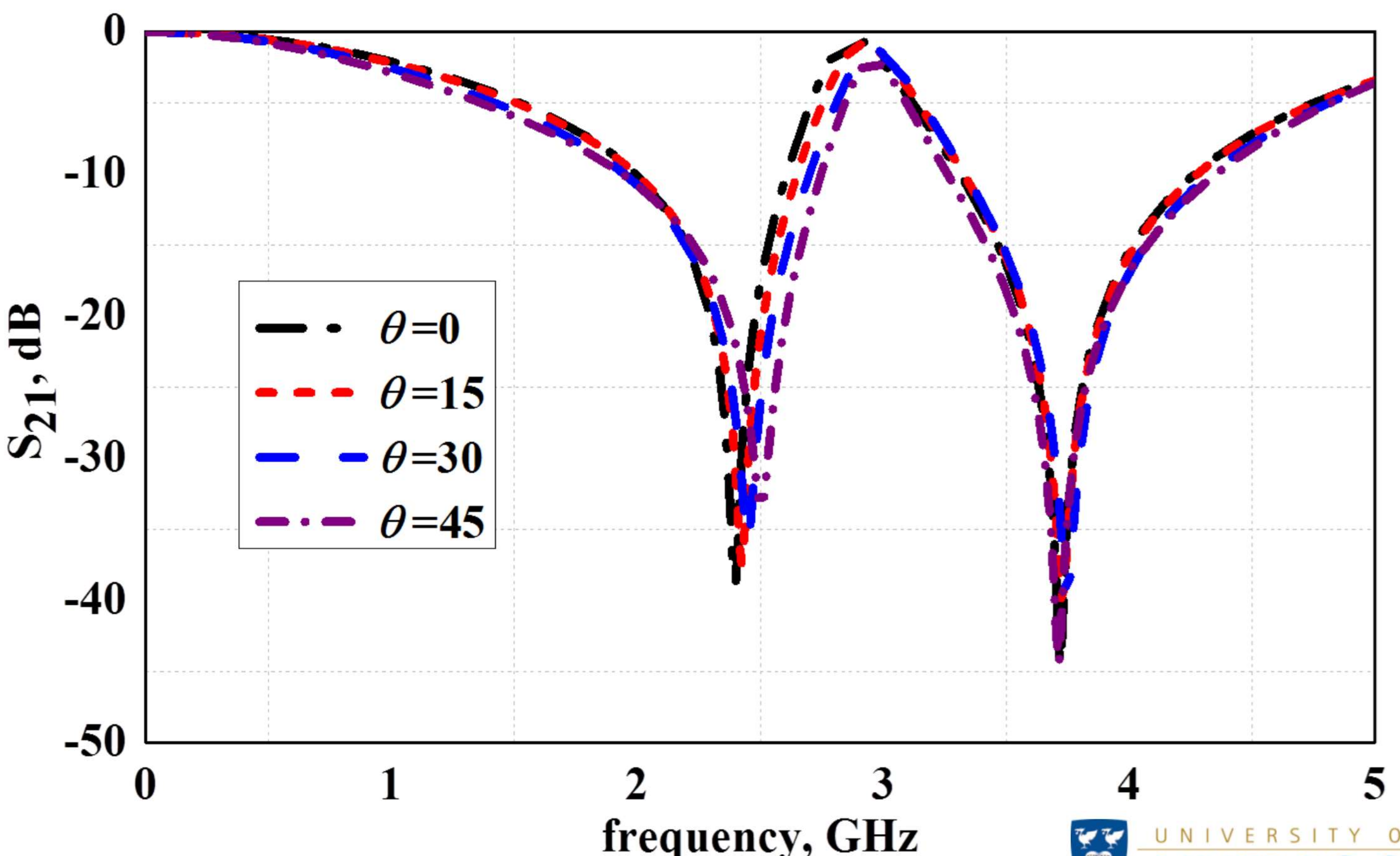
$f > f_0 \Rightarrow$ *Capacitive*



$$f_{1,2}^2 = \left| \frac{(L_1C_1 + L_1C_2 + L_2C_2) \pm \sqrt{(L_1C_1 + L_1C_2 + L_2C_2)^2 + 4L_1C_1L_2C_2}}{8\pi^2 L_1C_1L_2C_2} \right|$$

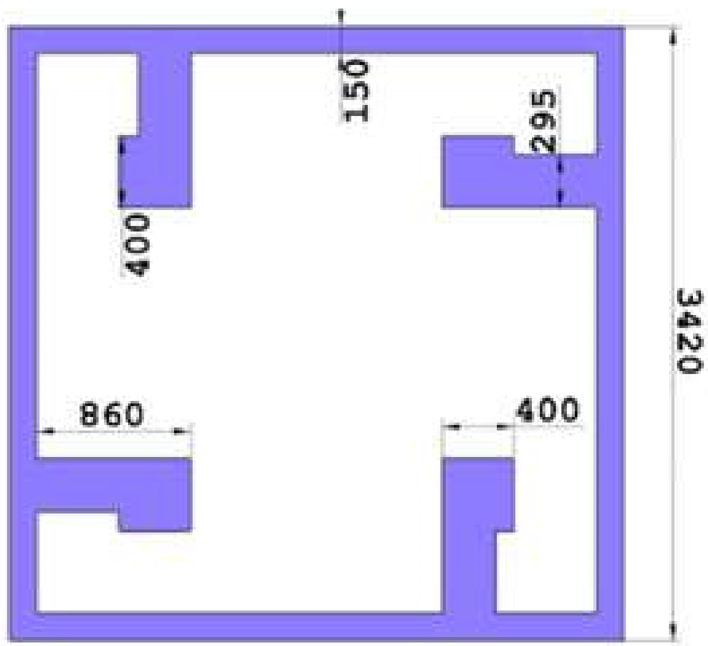
How to Improve the Selectivity of an FSS

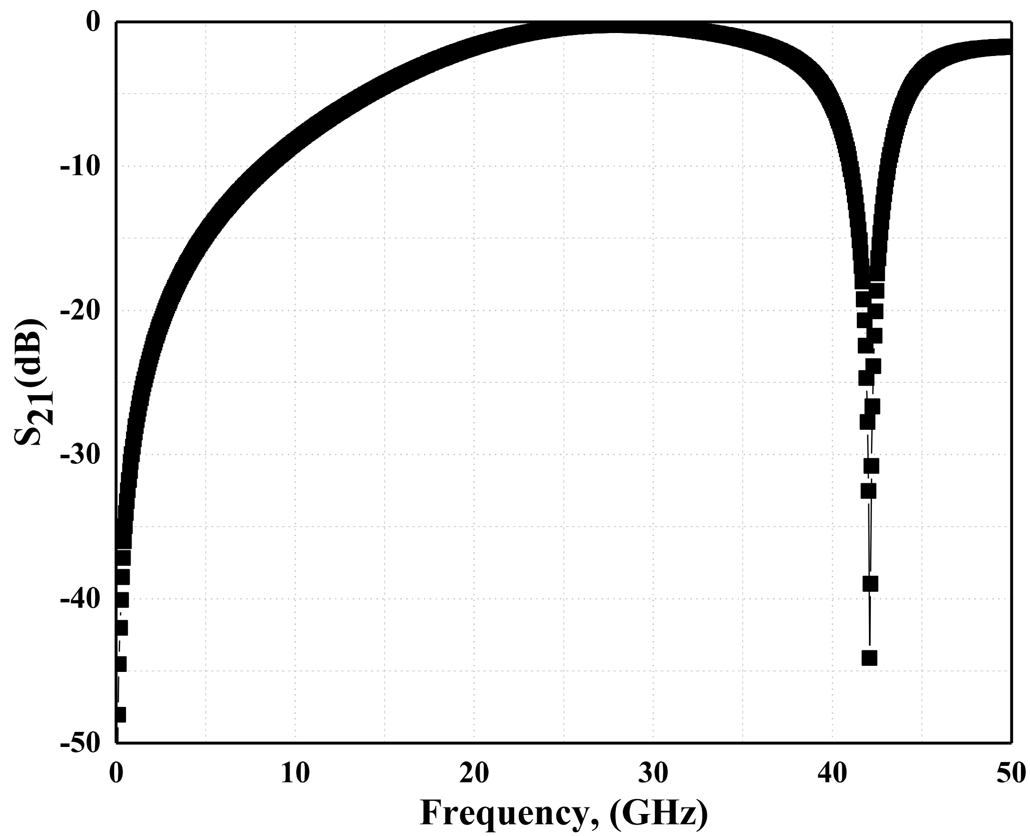
- Combining Two Structures: Naturally Easy for FSSs
  - Simulated vs Measured
  - Dual bandstop or bandpass with sharp selectivity.
  - Single layer: excellent angular stability



How to Improve the Selectivity of an FSS

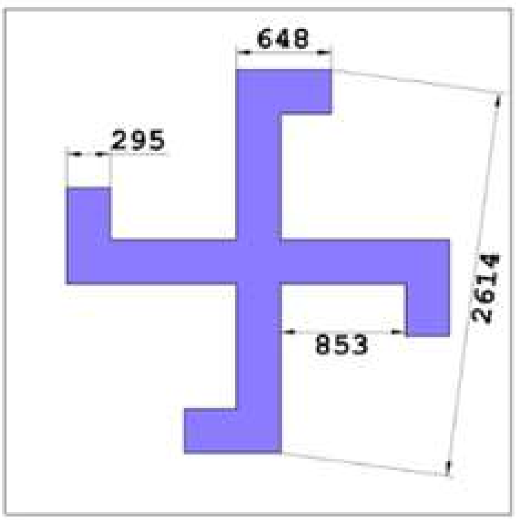
- Combining Two Structures: Naturally Easy for FSSs
  - Host structure: Mesh (unit: um)

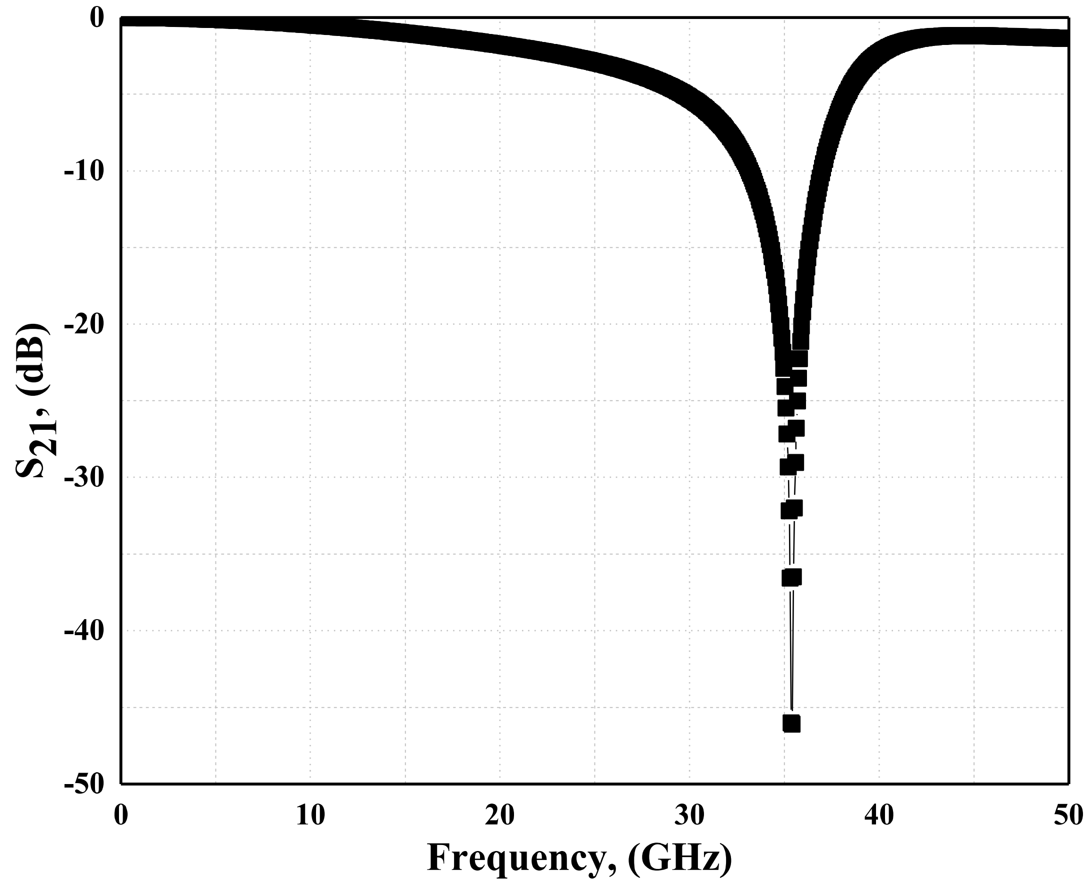




How to Improve the Selectivity of an FSS

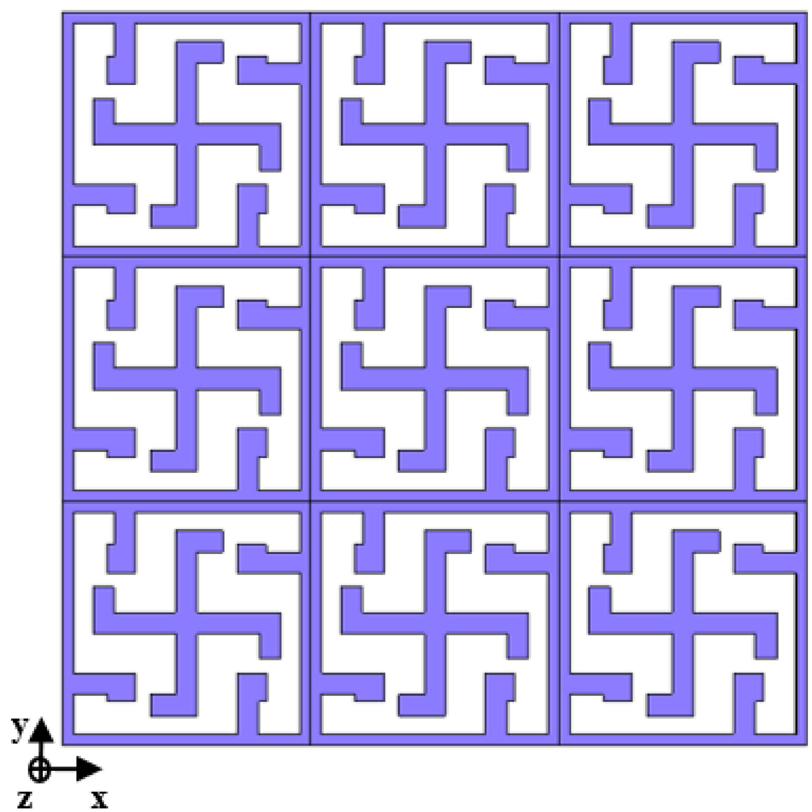
- Combining Two Structures: Naturally Easy for FSSs
  - Secondary structure: Swiss cross (unit: um)

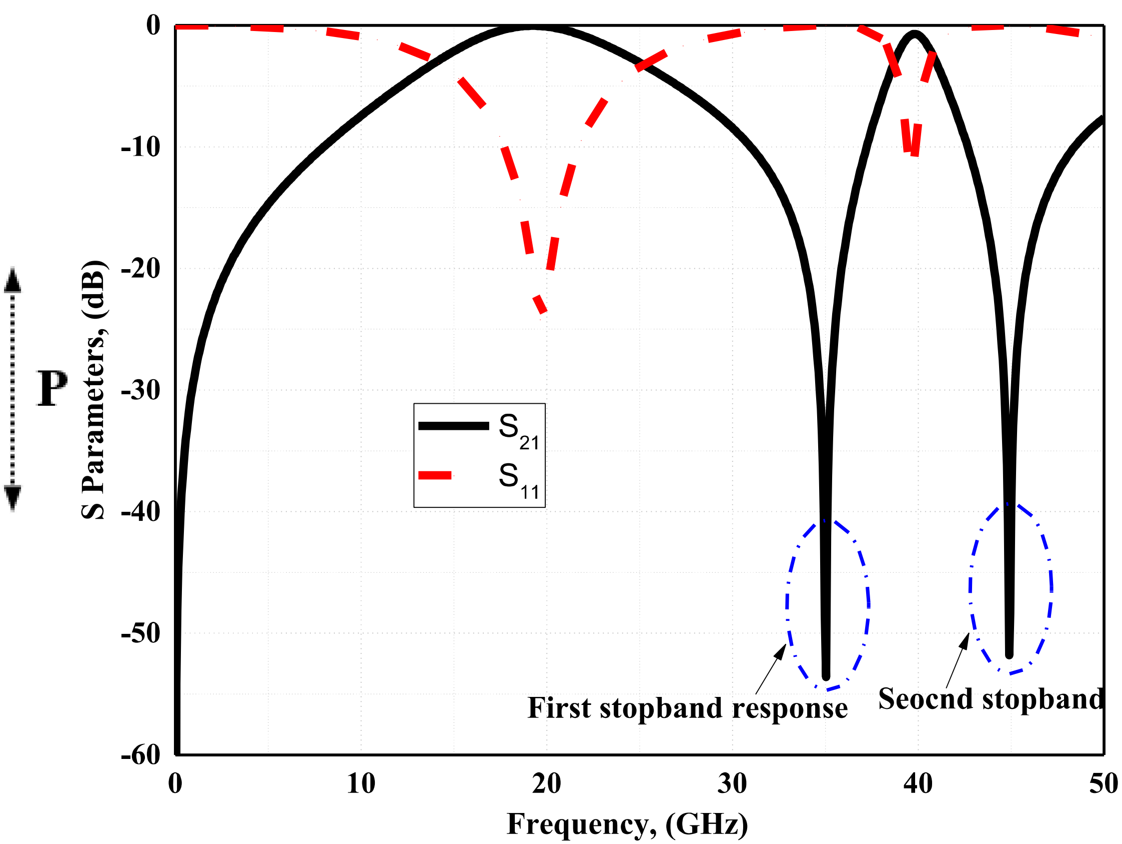




How to Improve the Selectivity of an FSS

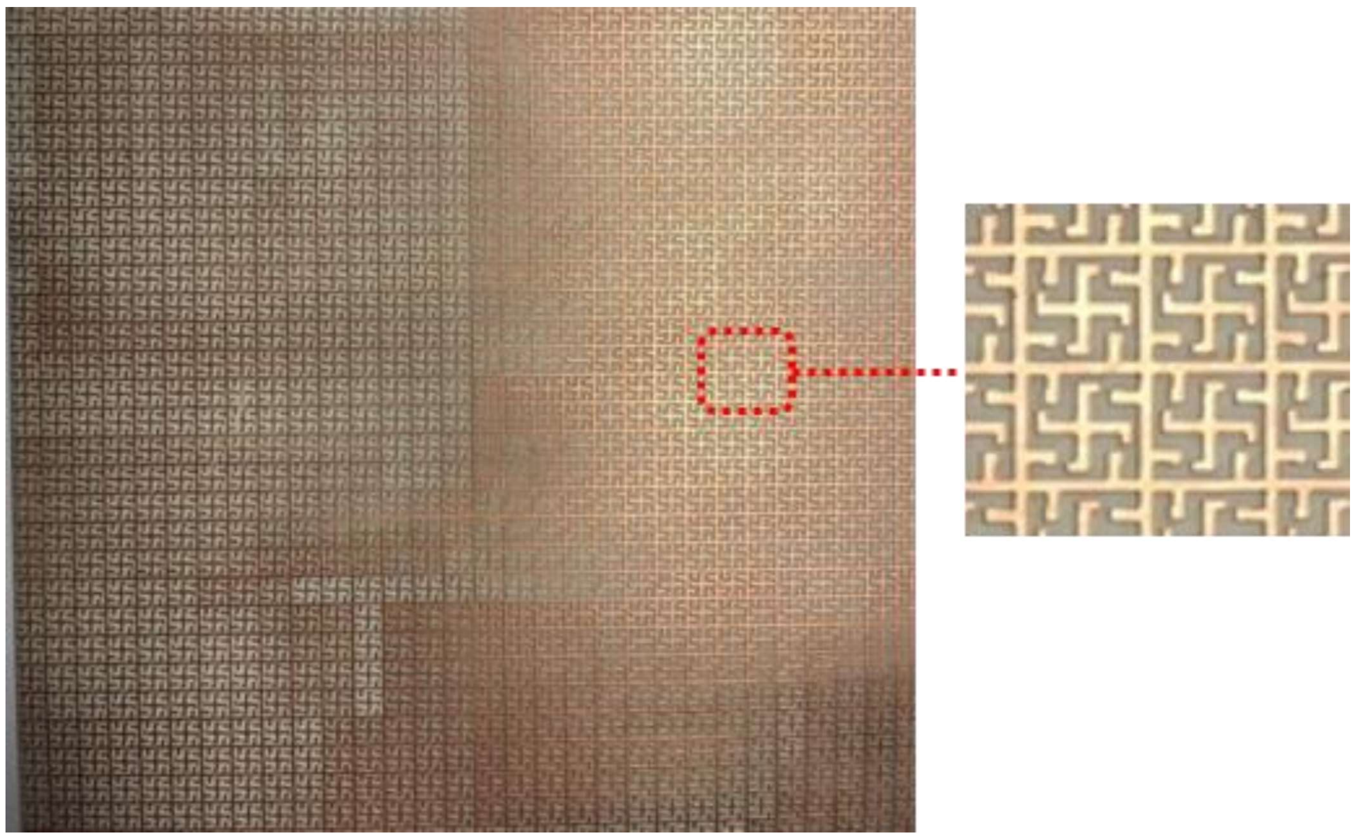
- Combining Two Structures: Naturally Easy for FSSs
  - Combining them together …
  - Two stopbands? Three passpands? Sharp bandpass?





How to Improve the Selectivity of an FSS

- Combining Two Structures: Naturally Easy for FSSs
  - Fabrication

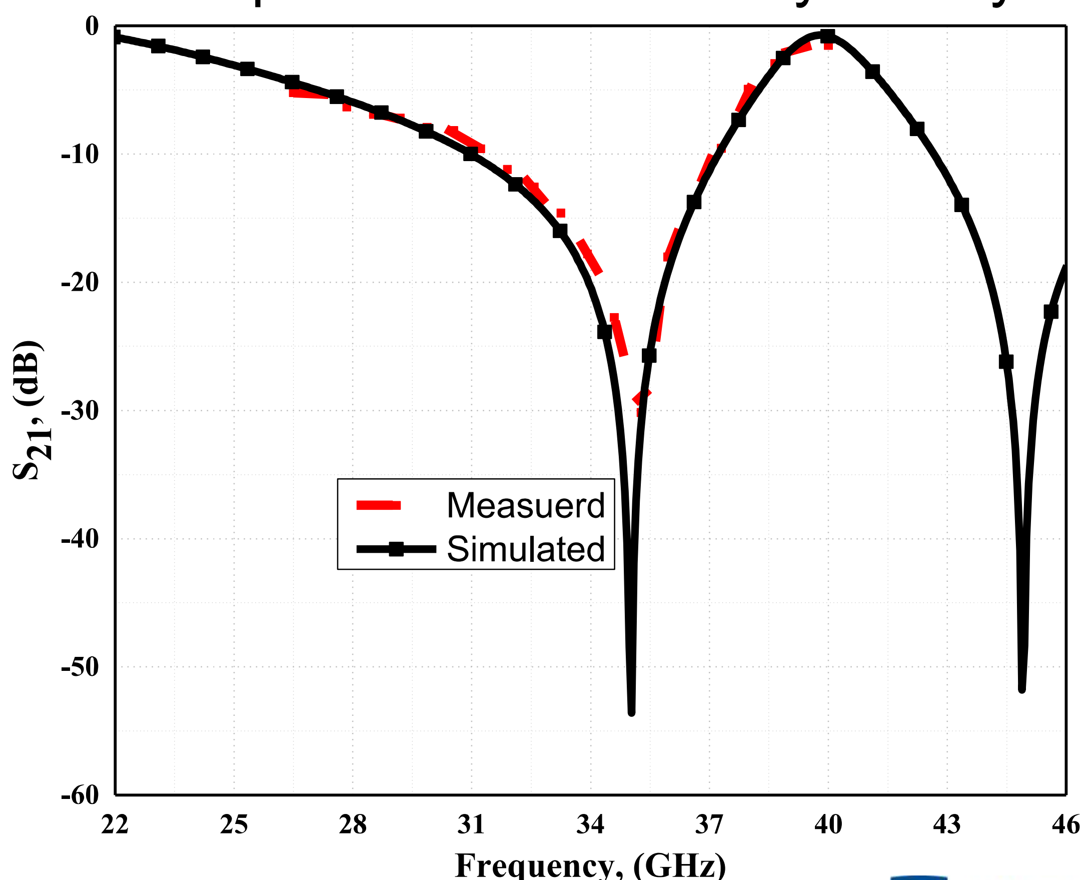


How to Improve the Selectivity of an FSS

- Measurement Setup

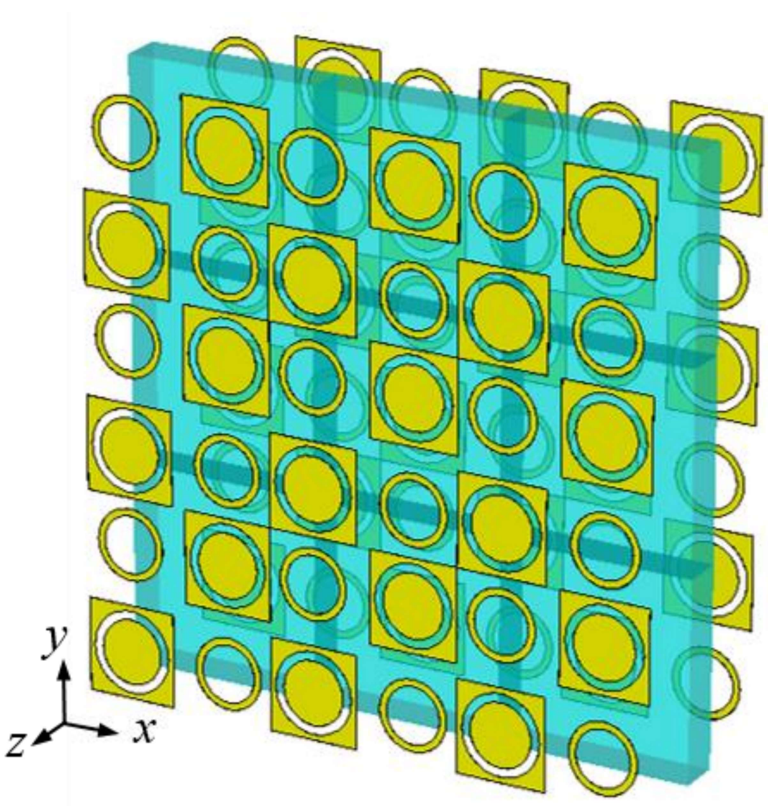
How to Improve the Selectivity of an FSS

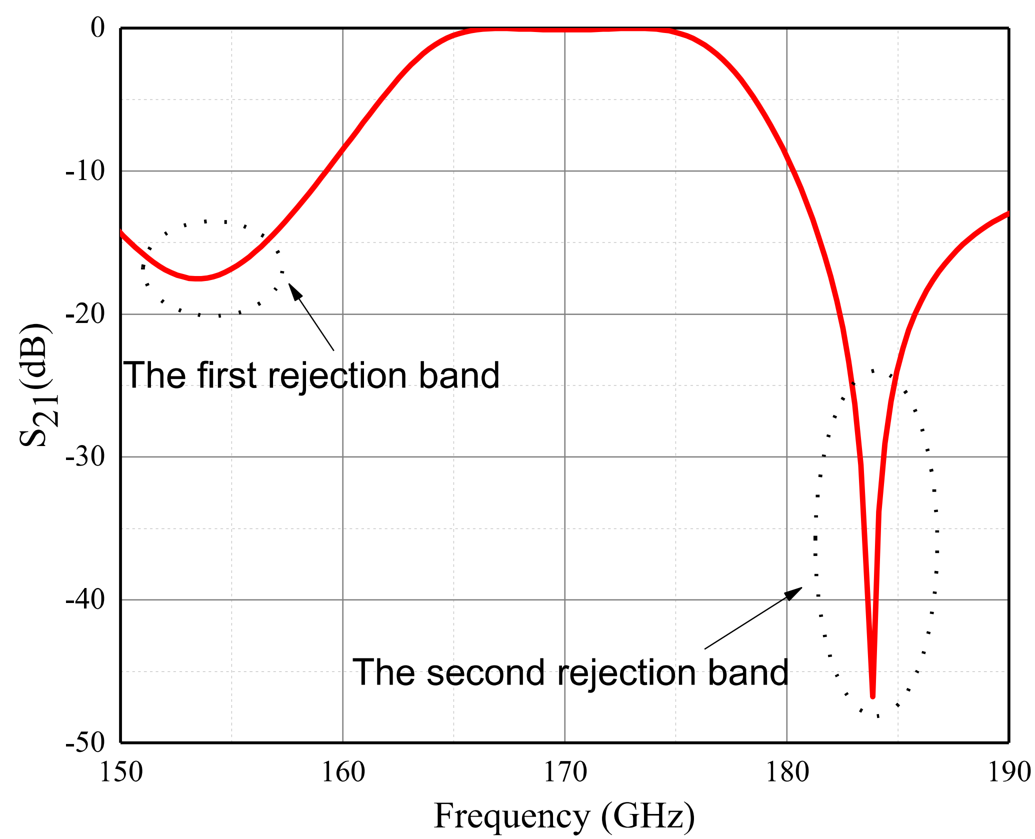
- Combining Two Structures: Naturally Easy for FSSs
  - Simulated vs. Measured (26.5 GHz – 40 GHz)
  - Single layer: excellent angular stability
  - Insensitive to polarization: due to symmetry



Future Work

- Combining Two Structures: **Two Layers**
  - Flat-top response
  - Separating 166 GHz and 183 GHz signals





Conclusions

- Frequency Selective Surfaces at Microwave, millimetre-wave and Terahertz frequencies
  - Both transmission and reflection have been exploited
  - Different structures can be combined to achieved advanced performance
- Superior performance achieved
  - Multiple passbands and stopbands can be easily realized.
  - These bands can be easily and independently controlled.
  - Single layer:
    - Easy fabrication
    - No alignment issue
    - Angular stability
    - Polarization stability
    - …

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